Photo courtesy Outokumpu

Designing with Stainless Steel

Bioclimatic hybrid façades

By Catherine Houska, CSI

An international design revolution is incorporating both traditional and new concepts to create bioclimatic sustainable architecture. Building energy reduction is a key goal for new and renovation projects designed to these principles, but it must be balanced against occupant well-being and the desire for fresh air and natural light.

Exterior walls are being transformed from relatively simple climate defensive mechanisms to more active membranes. Innovative hybrid second-skin designs incorporating shading systems are being used on award-winning projects around the world, and these concepts could be applied to a much broader range of buildings.[1]

Lifecycle assessments (LCAs) that consider materials' longevity are important because these exterior elements must withstand potentially corrosive environments with minimal or no maintenance. This can make stainless steel a logical choice for a multitude of demanding exterior applications.

Bioclimatic architecture refers to designing buildings and spaces (interior and exterior) using local climatic conditions to improve thermal and visual comfort. These designs incorporate systems that provide protection from summer sun, reduce winter heat loss, and make use of the environment (*e.g.* sun, air, wind, vegetation, water, soil, and sky) for heating, cooling, and lighting buildings.

If energy reduction was the only consideration, the optimal structure would have heavily insulated walls with no windows and recycled air. However, a balance must be struck with human health and productivity. Bioclimatic design elements go beyond adequate insulation and adjust environmental conditions so building inhabitants find them comfortable and pleasant. Designing with the local climate is both economical and ecologically sound.

Hybrid second-skin façades

Hybrid second-skin designs can increase the building inhabitants' connection with their surroundings. Exterior surfaces are shaded from the sun, reducing cooling requirements while still allowing daylight to enter. Some also shelter exterior surfaces from wind during the winter, reducing heating requirements. Both active mechanical systems that constantly adjust to the environment and fixed passive systems are used. All the systems can assist with managing outer and inner climates through varying degrees of integration with the building systems and improved natural ventilation and lighting.

These façades can be installed on existing and new structures. Various sun-screening technologies include:

- louvres;
- woven mesh;
- perforated screens; and
- green (*i.e.* vegetated plant) façade screens.

In new construction, these systems can transform the appearance of lower-cost buildings—such as simple concrete and glass shapes—at a much more reasonable price than a more elaborate curtain wall. On existing buildings, they can reduce energy expenses while updating the appearance.

Figure 1

Photo courtesy Centro Inox

Raffaello Sanzio Airport, located in Ancona, Italy, used fixed Type 316 sunscreens on the exterior of its new arrival and departure terminal buildings to avoid excessive building heat gain.

Active second-skin façades

There are many variations on active second-skin façades. Hybrid systems employ an operable shading system over the insulated glass façade, which maybe between inner and outer glass layers or be the outermost wall. The two layers can be from 0.2 to 2 m (0.7 to 6.6 ft) apart, and incorporate integrated sunshades and natural ventilation. All have computer-controlled mechanical operating systems that work in co-operation with the building's heating and cooling systems, making it possible for them to respond dynamically to varying conditions. By adjusting to the trajectory of the sun's rays, they maximize the benefits of solar radiation while minimizing heat gain.

Energy is necessary to operate these assemblies, and maintenance of the mechanical and sensing systems is required. Active second-skin façades have been particularly popular in Europe, Asia, and Australia, although some of the earliest examples are in North America (*i.e.* Occidental Chemical Centre, Niagara Falls, N.Y., completed in 1980).

Passive second-skin façades

The simplest second-skin façades have fixed semi-permeable membranes that allow the building to breathe and can consist of woven mesh, perforated sheets, green plant screens, or other forms of shading. These are popular for low-maintenance applications such as public buildings (Figure 1). Additionally, 'living walls' or 'vertical gardens' of plants—like those installed at Vancouver International Airport (*i.e.* Aquaquest at the Marilyn Blusson Learning Centre) and at the Vancouver Aquarium—provide some of the same sustainable advantages as green roofs and often use specially designed, corrosion-resistant, angled stainless steel planters to hold soil or growth media. All these systems are interfaces between the building's internal and external climates, but are not mechanically tied to the building's internal climate management systems.

Figure 2

Photos courtesy ThyssenKrupp AG

Type 316 stainless steel exterior sunscreens in varying styles were used on this German corporate campus. The systems actively adjust to seasonal and weather conditions in order to reduce energy requirements.

Like active screens, passive second-skin façades provide at least some shelter from harsh weather by reducing the impact of rain and direct sunshine. Ideal for projects where minimum maintenance is expected or where lower technology solutions are preferred, they are growing in popularity around the world.

Stainless steel selection

The term 'stainless steel' refers to a family of alloys that provide varying levels of corrosion resistance, strength, and formability. The most commonly specified stainless steels are Types 304/304L, 316/316L, and to a lesser extent, 2205, but many other grades have been used. Stainless steels provide much higher corrosion resistance than other common architectural metals, particularly when there is pollution and chloride salt exposure (primarily de-icing and coastal salt). There are numerous articles and industry association brochures to assist with stainless steel selection.[2]

Figure 3

Photo courtesy Ronstan Tensile Architecture

Plant screens were used along the balconies on the north side of Council House No. 2 (CH2) and over the roof deck for shelter from the sun.

Type 304/304L is generally appropriate for climate-controlled indoor and mild outdoor applications with low levels of urban pollution. If there will be some chloride salt exposure or higher pollution levels, Type 304 should be specified with a smooth finish and regular cleaning. The possibility of some staining between cleanings should be expected.

Since Type 316/316L contains a molybdenum addition, it is more corrosion-resistant than Type 304. It is usually suggested for exposure to low to moderately corrosive coastal and de-icing chloride salts, and moderate industrial or higher urban pollution levels. It was used for many of the projects that will be discussed in this article because of these conditions. It does not provide sufficient corrosion resistance for applications with high surface chloride salt accumulations or exposure to salt-water spray or splashing unless a smooth finish is specified and there will be regular cleaning. Care should be taken in specifying tightly-woven and cable products since chloride crevice corrosion can occur if there is exposure to high enough salt levels and a more corrosion-resistant stainless steel may be required.

Duplex stainless steels like 2205 are significantly stronger than non-cold-worked Types 304 and 316 and common structural carbon steels. Some, like 2205, can provide a significant improvement in corrosion resistance. Their high strength and corrosion resistance has made them an increasingly attractive choice for some applications. More resistant stainless steels than 2205 can be obtained. When an environment appears severe, the advice of a corrosion specialist should be obtained.

Since exterior air and humidity circulate through sunscreens, and segments are often sheltered from rain-washing, these spaces can be more corrosive than those boldly exposed to rain-washing. Designers should consider whether rain or manual washing is likely during material selection.

Sustainable design benefits

On average, international stainless steel production contains about 60 per cent recycled scrap content, and over 92 per cent of the stainless steel used in architecture, building, and construction is recycled at the end of service into new stainless steel.[3] In countries

Figure 4

Photo courtesy Cambridge Architectural

Across from the Québec border, Type 316 woven mesh provides sun shading and improved security for the U.S. Champlain port of entry.

with a high historical use of stainless steel, the recycled content may be as much as 90 per cent for Types 304/304L and 316/316L.

Numerous studies around the world have examined runoff from various materials (*e.g.* asphalt, metal, clay tile, and concrete). The primary purpose has been to determine whether the runoff is potentially toxic to humans, plants, or wildlife. Stainless steel has extremely low runoff levels (often below detectable limits), and it is not a biocide or otherwise toxic to the environment.

Figure 5

Photos courtesy Iwan Baan Studio

The perforated Type 316 screens around 41 Cooper Square give it a sculptural appearance while reducing its energy consumption.

German corporate campus

A seven-building corporate campus in Essen, Germany, designed by JSWD Architekten and Chaix & Morel, was awarded a pre-certificate in Gold from the German Sustainable Building Council (DGNB).[4] Based on the new German Certification for Sustainable Buildings, its energy consumption is expected to be 20 to 30 per cent below statutory requirements.

All the buildings are simple glazed shapes made interesting by their external Type 316 stainless steel sunshade systems. Building Q2—the corporate conference and training centre—has custom perforated stainless steel sunscreens that are a passive second skin. Active motorized sunshade second skin-façades were used on Building Q1, which has horizontal slats.

Buildings Q5 and Q7 have a playful combination of horizontal and vertical stainless steel slats. The solar control systems on both buildings have moveable triangular, square, and trapezoidal fins that both save energy and create a unique appearance. Used in combination with natural ventilation and geothermal heating and cooling, the systems eliminated the need for air-conditioning and greatly reduced winter heating requirements (Figure 2, page 20).

The Type 316 stainless steel slats were mounted on vertical shafts, which rotate to adjust their position. A dull abrasive-blasted finish was applied to one side of each slat and a highly polished finish to the other. Both seasonal sun position and current weather data are used by the computer system to adjust slat position to maximize natural lighting while minimizing summer heat gain.

The reflective surface faces inward and helps bring more natural light into the building while shielding it from sun and weather. Since this inner surface will not be naturally cleaned by rain, it would have been more prone to dirt accumulation and corrosion if a smoother finish had not been specified. The system can be used during all weather conditions—including high winds—and shields the building exteriors from harsh weather.

Council House 2

Melbourne, Australia's 10-storey Council House No. 2 (CH2)—a multi-award winning building completed in 2006—was the first commercial building to achieve Green Building Council of Australia's (GBCA's) highest possible Green Star '6' rating. The architect, DesignInc, reconsidered every aspect of the building during design. Relative to the city's Council House No. 1, it uses 85 per cent less

Figure 6

Type 316 perforated screens on the exterior of the San Francisco Federal Building helped eliminate the need for air-conditioning in 70 per cent of the building's occupied spaces and provided a link to the adjoining plaza.

electricity, 87 per cent less gas, and 72 per cent less potable water; carbon dioxide (CO_2) emissions associated with building operation were also reduced by about 60 per cent.[5]

Since air-conditioning is typically responsible for half the energy consumption of a typical Melbourne building, the designer used both active and passive sunscreens, natural ventilation, and conductive cooling of the ceilings to reduce energy requirements. The building's west side has an active second-skin façade of timber slat sunscreens covering the fully glazed exterior. They are supported by a lightweight Type 316 stainless steel tension cable system, allowing them to be pivoted vertically so they open and close in response to the time and sun's angle.

On the building's north side, which receives the most sun, passive green plant screens were used on the sides of balconies (Figure 3, page 20). They are supported by a Type 316 mesh and tension cable system and there are planters on each floor. The 1-m (3-ft) balcony projections shield windows from high-angle sun, and the green screens along their sides screen low-angle sun, filter glare, and connect occupants with their environment while providing privacy.

The vegetated screen extends upward to the roof and provides an arbour-like sunshade for the rooftop terrace. Like a vegetated roof, the natural green plant screen shelters the roof from the sun. The fully usable, attractive, shaded recycled wood roof deck also has a rock garden with living green sculptures supported by Type 316 mesh.

The success of vegetated building and landscaping privacy and sheltering screens depends on selection of appropriate vines for the region and maintenance pruning to encourage vine spread. Therefore, if service life is not limited, it is critical to use a supporting structure not reliant on coatings for corrosion resistance, as these cannot be reapplied without damaging the screen.

Corrosive coastal or de-icing salts and pollutants may accumulate on surfaces, and even natural fertilizers can be corrosive. Additionally, no part of the supporting structure should release chemicals or metals that kill plants (*e.g.* biocides), and its strength should not deteriorate over time with ultraviolet (UV) exposure, as will occur with plastics.

A high level of strength is necessary for these lightweight airy structures to withstand higher wind loads when fully vegetated. For these reasons, stainless steel is the logical choice for long-term installation. These screens naturally adjust to the seasons allowing more winter light to enter buildings.

Champlain port of entry

The border crossing between Champlain, N.Y., and Saint-Bernard-de-Lacolle, Que., is one of the five busiest between Canada and the United States, and the most important for Québec. A new building and gateway was completed for the U.S. port of entry's land side in March 2010. The project team consisted of Smith-Miller + Hawkinson Architects LLP (New York City), and contractor Northland Associates Ltd. (Liverpool, N.Y.).

Type 316 woven stainless steel, and the structural support system for it, was used for signage above the primary inspection booths, and as a sunshade system on the cargo processing facility's exterior. The screen significantly reduces solar glare, light pollution, and solar heat gain. Unlike conventional shading materials, architectural mesh also promotes airflow and enhances building security; it is also designed to meet an array of opacity, shading, and heat reduction requirements (Figure 4, page 22).

Transformative passive screens

Unlike tensile supported systems that parallel the insulated wall, lightweight framing supports for woven mesh or perforated panels allow the distance between the inner insulated skin and exterior hybrid second skin to vary, making seamless curving, geometric, and other shapes possible. This flexibility can dramatically change a new or existing building's appearance at a much lower cost than installing an undulating insulated curtain wall.

41 Cooper Square

41 Cooper Square, a new building at The Cooper Union, designed by Morphosis Architects, is the first U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED)-certified educational building in New York City (Figure 5, page 22). This 16,258-m^2 (175,000-sf) multi-award winning project received a Platinum rating for its innovative design.

The operable double-skin design uses Type 316 stainless steel perforated panels offset from a glass and aluminum window wall. This semi-transparent layer wraps around a traditional building shape, giving it a dramatic sculptural presence with areas of light and shadow. The perforated panels reduce heat radiation in the summer, shelter and insulate the inner wall in winter, and allow natural light to enter.

When the sculptured curving second skin was combined with natural ventilation, a vegetated roof, and radiant heating and cooling ceiling panels, it was possible to reduce the building's energy requirements by 40 per cent relative to a standard building of its type. A full-height atrium improves air circulation and provides additional indoor lighting. About 75 per cent of the building's regularly used interior spaces are lit with natural light.

San Francisco Federal Building

The San Francisco Federal Building, built in 2007, and also designed by Morphosis, is a slender 56,205-m^2 (605,000-sf) 18-storey tower connected to a four-storey annex and adjoining a public plaza (Figure 6). The use of sunscreens on both the building and adjoining plaza make a visual connection between them. The structure was the first office tower in the United States to give preference to natural ventilation—about 70 per cent of the work area is naturally ventilated rather than air-conditioned. The narrow tower design also means 90 per cent of the workstations have natural lighting and operable windows.

The folded, perforated Type 316 stainless steel sunscreens cover full-height glass window walls, shielding them from heat gain, sheltering them from inclement weather, and allowing natural light into the building. The computer-controlled mutable skin adjusts to daily and seasonal climate fluctuations. The building surpasses the U.S. General Services Administration's (GSA's) energy performance criteria by 50 per cent and sets new standards for passive climate control.[6]

Guangzhou 2^{nd} Children's Activity Centre

Completed in 2006, Guangzhou 2^{nd} Children's Activity Centre (China) provides teaching, performance, and exhibition space for after school and weekend arts-education courses for primary and secondary school students (Figure 7). Designed by Steffian Bradley Architects (SBA), this 42,735-m^2 (460,000-sf) concrete building has a capacity for 20,000 people. The dramatic and seamless compound curves on the exterior were made possible by the use of a Type 316 stainless steel mesh metal panel system. Site orientation and green spaces maximize sustainability by capitalizing on shading, daylight, and wind.

Figure 7

Photo courtesy Steffian Bradley Architects

Guangzhou 2^{nd} Children's Activity Centre (China) was wrapped in stainless steel mesh to reduce energy requirements and create a seamless sculptural shape.

Figure 8

Photo courtesy Outokumpu

Contoured, ribbon-like, softly reflective pieces of stainless steel hover away from the Stockholm Congress Centre, creating its distinctive appearance.

The building is set on one storey of columns so the outdoor plaza continues beneath the building, which retains open circulation at street level and allows pedestrians to enjoy the natural surroundings. The arrangement of building elements relative to the prevailing wind directions and the open ground and upper floors allows for natural ventilation, eliminating the need for air-conditioning in common spaces. The mesh also hides the HVAC units. The strategic placement of a curved element against a linear element is intended to maximize natural light exposure and minimize shadow line coverage, while creating a distinctive identity and enhancing energy savings and sustainability.

Stockholm Congress Centre

Sweden's new Stockholm Waterfront, a congress centre located along the waterfront in the heart of the city, is a layered structure designed for significant energy reduction. Contoured, ribbon-like, softly reflective pieces of stainless steel hover away from the structure, creating its distinctive, undulating appearance.

Long service life, low-maintenance materials were necessary for the sunscreen, which angles outward from the wall. It used 3500 Z-shaped duplex 2205 stainless steel sections, 3 to 16 m (9.8 to 52.5 ft) in length. The sunscreen has a semi-reflective matte finish. The screen angle reflects away summer sun while allowing natural light to enter. The seasonal angle of the sun changes—in winter, sunlight passes through the wall to passively heat the building.

Although Stockholm does not have a severe coastal environment, sections of the sunscreens are sheltered from rain. The architect, White Arkitekter of Stockholm, obtained advice from the stainless steel producer and specified the more corrosion-resistant, higher-strength duplex stainless steel 2205 (Figure 8). Completed in early 2011, the building is expected to receive green building certification.

Conclusion

Successful sustainable bioclimatic design requires material selection that can last the structure's life. Site analysis should consider exposure to pollution, corrosive salts, and the likelihood of manual or rain cleaning when conducting a lifecycle analysis. Stainless steel is the most corrosion-resistant of the readily available architectural metal options and, therefore, is being used for applications ranging from sunscreens to landscaping.

When an appropriate stainless steel alloy and finish are specified, it will provide attractive performance over the building's life, and has no toxic runoff that might harm the environment. Stainless steel has a recycled content of at least 60 per cent, and 92 per cent of the stainless steel used in architecture is reused to make new material. For these reasons, stainless steel is an ideal choice for sustainable architecture.

Bioclimatic design concepts can have a substantial impact on the sustainability and comfort of Canadian buildings in temperate and cold climates. The Stockholm Congress Centre and German corporate campus projects mirror concepts being used in Canada, including taking advantage of the seasonal angles of the changing sun and using second-skin façades to shelter windows from winter weather. As designers become more familiar with the design concepts and benefits of second-skin bioclimatic façades, their use in Canada will continue to grow.

Notes

[1] This author would like to acknowledge the International Molybdenum Association (IMOA) and the Nickel Institute for its assistance in the preparation of this article.

[2] For further information on stainless steel selection and design, see various articles by this author. They include "Sustainable Stainless Steel Architectural Design," *Construction Canada* (September 2009), "Designing on the Waterfront," *The Construction Specifier* (November 2007), "Pushing the Design Envelope with Structural Stainless Steel," by this author and Kirk Wilson, *The Construction Specifier* (April 2007), "Architectural Metal Corrosion: The de-icing salt threat" *The Construction Specifier* (December 2006), "Metals for Corrosion Resistance: Part II" *The Construction Specifier* (November 2000). More information can also be found in *Guidelines for Corrosion Prevention* by the Nickel Institute (pub. 11 024), and in *Which Stainless Steel Should be Specified for Exterior Applications* by the International Molybdenum Association (IMOA).

[3] For more information, visit the International Stainless Steel Forum (ISSF) website at www.worldstainless.org.

[4] Additional information can be found in the October 2010 issue of *ThyssenKrupp Quarter* and company press releases.

[5] For more information, see "CH2 6 Stars, but How Does it Work?" and "CH2 6 Stars, but is it Architecture?" in the January/February 2007 issue of *Australian Architecture.*

[6] See "Morphosis and Arup Engineers Create Dynamic Form that Follows Function for the U.S. Federal Building in San Francisco," by Joann Gonchar in the August 2007 issue of *Architectural Record.*

Catherine Houska, CSI, is a senior development manager at TMR Consulting. She is a metallurgical engineering consultant specializing in architectural metal specification, restoration, and failure analysis. Houska has authored more than 128 publications, including several features for Construction Canada *and* The Construction Specifier. *She can be reached via e-mail at chouska@tmr-inc.com.*